Neurodevelopmental Aspects of Adolescence: Commentary on Conference on Strength and Potentials of Adolescence

Surprisingly, specific aspects of the normal neurodevelopment of adolescence were omitted from the Conference on Strength and Potentials of Adolescence, held in 1991 by the Committee on Public Health of the New York Academy of Medicine.

The term "biology" is included in one presentation[1] but not discussed, and Blum's[2] summary of the Conference emphasizes: the "promotion of healthy behavior," wishing this theme "were stronger"; the need for "carefully examining problems"; and the need for longitudinal research in the three models presented by Brooks-Gunn and Paikoff,[3] which addressed ecology, family systems, and vulnerability. No Conference participant discussed any neurobehavioral aspects of adolescence, which overlap with and impact on all three models. In my experience,[4–9] the study of such aspects does not necessitate expensive programs. The following summary may suggest ways in which the potentials of adolescents might be viewed with reference to their neurodevelopmental milieu.

Neurodevelopmental Vulnerability of Adolescents

Essential aspects of typical adolescents' behavior are illuminated when one considers the normally late anatomical maturation of the orbital frontal lobes, in terms of both myelination[10] and synaptic cell density.[11] The maturation of the frontal lobe system normally does not even approach completion before puberty and can be further delayed in its normally slow process, lasting beyond puberty and way beyond its initial spurt around age 4 or 5.[5–9] Such maturational delay—as is the case with all late maturing systems—is typically associated with a dearth of specifically challenging ecological input, such as is provided by family and school systems.

Behavioral maturation is partly a function of orbital frontal lobe maturation. Consider that the adolescent age group contributes the highest percentage of all fatal car accidents and crimes.[8] Similarly specific, although minor, "misbehavior" has been identified in children with attention deficit disorder (formerly called minimal brain dysfunction).[5–9] Obviously, the consequences of young children's immature frontal lobe system are not as severe as those of adolescents, who face more complex demands on action behavior. Note that the most descriptive term, "impulsivity," does not adequately specify the characteristic aspects of the form (not of the content) of action behavior shared by children and adolescents. "Immaturity" seems more accurate, both from a neurodevelopmental and behavioral perspective.

Frontal Lobe Mediation of Complex Activities

Essential frontal-lobe–governed behavior concerns the ability to plan a course of rule-governed action while considering several potentially conflicting options. Mature frontal lobe functioning enables one to consider the future (late) consequences of acts and to keep in mind the plan and the set of rules, ready to change them appropriately according to suddenly intervening circumstances during an ongoing activity (e.g., while driving a car).[12,13] Specifically, such "executive" functioning includes the ability to hold the set of rules "on line" in representational "working" memory, enabling nonimpulsive, "delayed" responses,[14] as was noted in a polygraph study of autonomic responses to social stimuli.[15]

Previous clinical observations and results from experimental testing with control groups using the Trail Making Test B and/or the Clinical Narratives Test[7–9] are congruent with the neuroanatomical evidence in specifically implicating frontal lobe dysfunctioning in several behavioral disorders ranging from attention deficit disorder to "delinquency" and "crime."[5–9] Various objective test findings also support these findings: Zambelli and colleagues'[16] studies of auditory evoked potentials in formerly hyperactive boys; Duffy's[17] BEAM studies of some adolescents; and a

PET scan study of adults with persistent attention deficient disorder by Zametkin et al.[18]

Future Research

Future research on orbital frontal lobe development and associated behavior could proceed in two steps:

1. Evaluation of comparison groups by the specific analysis of the form (not content) of accounts of actual and/or invented action behavior. Emphasis would be placed on the ability to switch ongoing activities appropriately, as detected especially by a form analysis of the Clinical Narratives Test.[7–9] Typically, such accounts are already available in school composition assignments and/or in recorded talk material from "rap" sessions. Objective tests, such as EEG, BEAM, PET, and/or MRI, as well as additional neuropsychological tests of frontal lobe functioning, such as the Trail Making Test B or the Wisconsin Card Sorting Test, the utility of which has been demonstrated,[4–9] can be added.
2. After identification of low-level performance on these tests (implicating maturational lag of the frontal lobe system), the poor performers can be divided into an experimental and a control group. The experimental group can be exposed to specific exercises, characterized by challenging the specific frontal-lobe-mediated abilities described above. All such exercises are actually or potentially available to school systems. Examples of such activities might include certain sports or other physical activities, certain video games such as simulated car driving[19], and/or narrated complex riddles. All such exercises would especially tap the aforementioned frontal lobe functions, including rule- (value-) based decision making during the reprogramming of an ongoing activity.

As an inducement for such exploration of adolescence-related social problems, recall that initially inexpensive clinical studies[4–9] were able to implicate specifically the frontal lobe system before support by expensive, even intrusive, laboratory test results two decades later.

This sequence of events should encourage experienced clinicians in diverse psychosocial fields of endeavor to work on this pressing problem.[20]

Practical Application for Remediation

If on re-testing the experimental group shows progress over the control group, prescribed specific activities can be recommended as appropriate, refined, action-based exercises to foster the maturational process of the late-evolving frontal lobe system.

A caveat is in order: Practice has to feature a hands-on type of action (including external and "inner speech"). Although cognitive instruction is necessary to establish a system of rules (e.g., values), didactic instruction alone has proven insufficient. Such failures are related to the well-known fact that knowing and doing are rarely the same. Such a "dissociation between knowing and doing"[12] is characteristic of frontal lobe dysfunction.

In general, practice has long been observed to increase functioning. Recent technologically refined methods have been able to pinpoint neuroanatomical brain changes caused by practice.[21,22]

Practice is particularly essential for postnatally late evolving functions, such as those mediated by the frontal lobe system. It is reasonable to conclude that age-inappropriate overprotection of children and adolescents (which does not challenge their abilities but encourages passivity and takes away responsibility for the youngsters' actions and their consequences) impedes and delays such already normally late-evolving maturation, so that the problems of social "misbehavior" can persist beyond adolescence into young adulthood, as reflected in crime statistics.[8,20]

ANNELIESE A. PONTIUS, MD
Associate Clinical Professor of Psychiatry, Fellow
Harvard Medical School, Boston
New York Academy of Medicine

References

1. Haggerty RJ. Health policy initiatives in adolescence. *Bull N Y Acad Med.* 1991;67:515–526.
2. Blum B. Summation. *Bull N Y Acad Med.* 1991;67:625–628.

3. Brooks-Gunn J, Paikoff RL. Promoting healthy behavior in adolescence: the case of sexuality and pregnancy. *Bull NY Acad Med.* 1991;67:527–547.
4. Pontius AA. Neurological aspects in some types of delinquency, especially among juveniles. *Adolescence.* 1972;7:289–308.
5. Pontius AA. General discussion. IN: De La Cruz FF, Fox BH, Roberts RH, eds. *Minimal Brain Dysfunction.* New York: *Ann N Y Acad Sci.* 1973;205:61–63.
6. Pontius AA. Dysfunction patterns analogous to frontal lobe system and caudate nucleus syndromes in some groups of minimal brain dysfunction. *J Am Med Women Assoc.* 1973;28: 285–292.
7. Pontius AA. Basis for a neurological test of frontal lobe system functioning up to adolescence: a form analysis of action expressed in narratives. *Adolescence.* 1974;9:221–232.
8. Pontius AA, Ruttiger FK. Frontal lobe system maturational lag in juvenile delinquents, shown in Narratives Test. *Adolescence.* 1976;11:509–516.
9. Pontius AA, Yudowitz BS. Frontal lobe system dysfunction in some criminal actions as shown in Narratives Test. *J Nerv Ment Dis.* 1980;168:111–117.
10. Yakoviev PI, Lecours AR. The myelogenetic cycles of regional maturation of the brain. In: Minkowski A, ed. *Regional Development of the Brain in Early Life,* Oxford: Blackwell; 1967.
11. Goldman-Rakic PS. *The Brain, Cognition, and Education.* New York: Academic Press; 1986, pp. 233–258.
12. Teuber HL. The riddle of the frontal lobe function in man. In: Warren JM, Akert K, eds. *The Frontal Granular Cortex and Behavior.* New York: McGraw-Hill; 1964.
13. Luria AR. *Higher Cortical Functions in Man.* New York: Basic Books; 1980.
14. Goldman-Rakic PS. Circuitry of primate prefrontal cortex and regulation of behavior by representational memory. In: Blum F, ed. *Handbook of Physiology: Nervous System,* vol. 5. *Higher Functions of the Brain.* Bethesda, MD: American Physiological Society; 1987:373–417.
15. Damasio AR, Tranel D, Damasio H. Individuals with sociopathic behavior caused by frontal damage fail to respond autonomically to social stimuli. *Behav Brain Res.* 1990;41:81–94.
16. Zambelli AJ, Stamm JS, Maitinsky S, Loiselle DL. Auditory evoked potentials and selective attention in formerly hyperactive adolescent boys. *Am J Psychiatry* 1977;134:742–747.
17. Duffy FH. The BEAM method for neurophysiological diagnosis. In: Nottebohm F, ed. *Hope for a New Neurology. Ann N Y Acad Sci.* 1985;457:19–34.
18. Zametkin AJ, Nordahl TE, Gross M, et al. Cerebral glucose metabolism in adults with hyperactivity of childhood onset. *N Engl J Med.* 1990;323:1361–1366.
19. Pereira J. Computer, a tool for women, a toy for men. Video games help boys get a head start. *Wall Street Journal,* March 16, 1994, p B4–B5.
20. Moran M. Public health strategies urged to prevent violence. *Psychiatric News,* November 18, 1994, pp 6–7.
21. Barinaga M. Watching the brain remake itself. *Science.* 1994;266:1475–1476.
22. Diamond ME, Huang W, Ebner FF. Laminar comparison of somatosentory cortical plasticity. *Science.* 1994;265:1884–1888.